

## Design of Ka-Band Microstrip Patch Antenna For Band-II 5g Applications

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**Abstract.** This project has gotten to be basic in cutting-edge portable communication, especially with the coming of 5G systems, which request higher frequencies and made strides in execution. This consideration presents a novel plan for a microstrip patch antenna wire particularly designed to work the Ka-Band, focusing on frequencies of 3 GHz and 5GHz, which are vital for Band-II 5G applications. The fundamental objective of this inquire is to upgrade the antenna's pick-up and by and large radiation characteristics by joining an inventive arrangement of space shapes inside a conventional rectangular patch. By presenting two hammer-shaped openings and a rectangular space put deliberately between them, the plan points to make a more effective emanating structure. This approach makes strides in current conveyance and increments the compelling opening, driving to prevalent antenna wire execution. The plan handle included broad optimization of the opening measurements utilizing the CST Studio Suite test system, which permitted exact control over the antenna's electromagnetic properties. The optimization centered on key components such as return misfortune, transfer speed, pick up, and radiation design to guarantee that the antenna wire meets the exacting necessities for 5G applications. A careful comparative investigation was conducted to evaluate the proposed antenna against past plans, concentrating on execution measurements such as pick up, radiation effectiveness, and beamwidth. The comes about illustrate a critical advancement in pick up, upgraded directivity, and a more extensive operational transfer speed for the proposed plan. The think about highlights that the imaginative opening setup not as it were boosts the antenna's execution but moreover keeps up a low-profile plan, making it perfect for integration into compact portable gadgets.

**Keywords**-- Microstrip patch antennas, 5G, Ka-Band, gain, slot shapes, CST Studio Suite, bandwidth, directivity, radiation efficiency, mobile devices.

## INTRODUCTION

Microstrip patch antennas are broadly utilized in portable communication systems since of their low profile, cost effectiveness, compact size, ease of manufacture, and versatility to diverse gadget shapes. These antenna wires discover applications in a assortment of innovations such as versatile phones, RFID, GPS, and radar systems. They are especially fundamentally to the advancement of 5G remote communication systems. The millimeter-wave (mmWave) band, plays a significant part in 5G systems. The two most critical frequency groups, as assigned by the FCC, are 3 GHz and 5 GHz. CST Studio Suite, a effective electromagnetic reenactment program, gives a few points of interest for the plan, reenactment, and optimization. In this project, CST innovation improves the antenna wire plan handle in a few key ways. CST Studio Suite offers exceedingly precise electromagnetic field reenactments, which are significant for planning and optimizing antenna structures. The capacity to reenact the antenna's behavior inside the required frequency ranges guarantees that the plan meets the exacting necessities of 5G applications. The software's progressed model capabilities permit real-time alterations, which streamline the refinement handle and guarantee the last plan is both successful and commonsense. CST gives nitty gritty investigation apparatuses that permit for the assessment of key execution parameters such as pick up, VSWR, transmission capacity, and radiation designs. In this consider, CST empowered a careful appraisal of the antenna's execution at the basic 3 GHz and 5 GHz frequencies, guaranteeing the plan met the essential details for tall pick up, low VSWR, and wide transfer speed. Another advantage of CST is the capacity to compare the proposed antenna plan with existing microstrip patch antenna wires. Nitty gritty recreations permitted for approval of the proposed design's predominant execution in terms of key parameters. CST's comparison devices given a clear, coordinate assessment, fortifying the study's conclusions and illustrating the viability of the optimized space arrangement and signal transmissions.

## DESIGN OF ANTENNA

### Antenna Specification

The design of the patch antenna is optimized for the frequency band from 3 to 5 GHz at a center frequency of 4 GHz. The end of the antenna design consists of an FR4 substrate, where the relative permittivity ( $\epsilon_r$ ) was taken to be 4., with a substrate height of 3.6mm, striking a good balance between compactness and performance. The length and width of the patch are connected with very effective radiation characteristics, with the length set to 17mm and the width set to 22 mm. The overall size of the substrate extends to 34mm in length and 44 mm in width for structural stability and ground support. Impedance matching and signal transmission take place within the designed antenna techniques. A microstrip feed line is used. The length of the feed line is 17mm, while its width is set at 3 mm. The width of the feed slot is 3mm, leading to the improvement of bandwidth and radiation efficiency. The simulated results indicate a gain of 3.04 dB from CST Studio, while the constructed prototype attained a gain of 3.4 dB, thus displaying the advantages that come with practical construction. Moreover, the E-field strength came to be 16.7 V/m, radiation efficiency is -3.4dB, and total efficiency is -4.5dB. The optimization of the antenna design for wireless applications has shown advantages in supporting compact structures with efficient radiation characteristics and improvements in fabrication.

## Process And Design

In the design process, the operating frequency bands for antennas, the selection of substrate materials, and several performance evaluation parameters are defined. The dielectric characteristics are chosen for the substrate, which play an important role in determining the antenna efficiency and bandwidth. Having defined these dielectric properties, patch dimensions can be derived. A slot structure is added to slightly enhance the performance bandwidth. At this point, the prototype was designed, and advanced electromagnetic simulation software was utilized to estimate gain, directivity, radiation efficiency, field distribution, and other relevant parameters. A second prototype was built for testing under practical conditions; from a silicone prototype, the real responses were compared with those simulated to note any differences that might arise from tolerances introduced during the manufacturing process because of the environmental conditions. This process is then meticulously verified, and trials are performed to ensure undaunted performance of antennas, especially for demanding applications in wireless communications.

To calculate the Patch Width(WP)

$$\epsilon_{\text{eff}} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left( \frac{h}{W} \right)^{-1/2} \quad (1)$$

To calculate the Patch Length(WL)

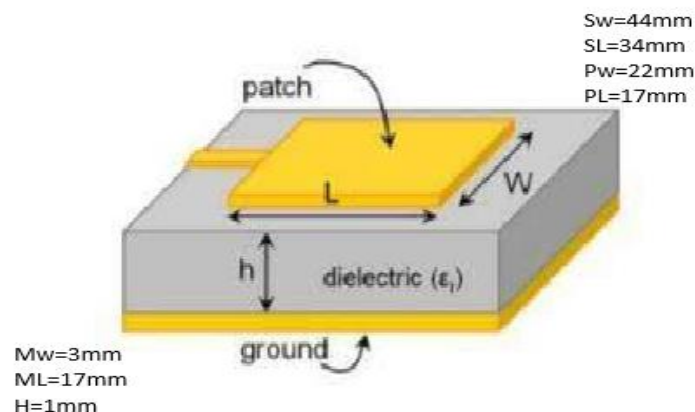
$$L = \frac{c}{2f\sqrt{\epsilon_{\text{eff}}}} \quad (2)$$

The effective dielectric constant.

$$\epsilon_{\text{eff}} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left( \frac{h}{W} \right)^{-1/2} \quad (3)$$

To Calculate the width of Microstrip FeedLine(WX)

$$W_x = \frac{c}{2f\sqrt{\epsilon_{\text{eff}}}}$$



**FIGURE1.DevelopedAntennain 3D**

**TABLE1 DIMENSION OF THE PROPOSED DESIGN**

| S.NO | PARAMETERS                                  | SIMULATED | MEASURED  |
|------|---|-----------|-----------|
| 1    | Dielectric Constant of the Substrate (Fr-4) | 4(nounit) | 4(nounit) |
| 2    | Substrate Length(SL)                        | 34mm      | 32mm      |
| 3    | Substrate Width (SW)                        | 44mm      | 42mm      |
| 4    | Patch Length(PL)                            | 17mm      | 15mm      |
| 5    | Patch Width(PW)                             | 22mm      | 21mm      |
| 6    | Microstrip Length(ML)                       | 17mm      | 14mm      |
| 7    | Microstrip Width (MW)                       | 3mm       | 2.7mm     |
| 8    | Wavelength( $\lambda$ )                     | 17mm      | 17mm      |
| 9    | Height                                      | 1mm       | 1.2mm     |

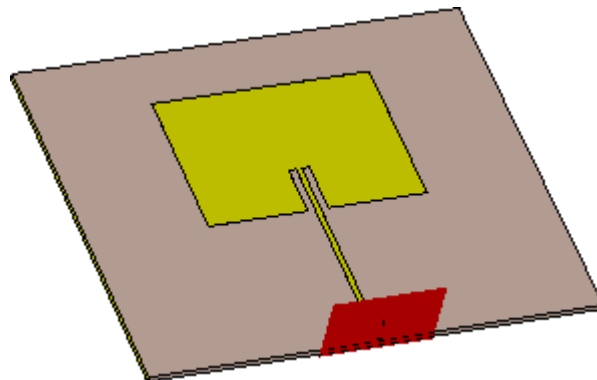


FIGURE2 Simulation Model

### PARAMETRIC STUDY, SIMULATED AND MEASURED RESULTS

The antenna consists of a radiating patch, a dielectric substrate, and a ground plane that have been properly optimized for adequate impedance matching and radiation characteristics. Return loss, VSWR, and radiation patterns were analyzed to verify good impedance matching and good radiation performance. A directional far-field radiation pattern received from the simulation is concerning the satisfactory expected performance characteristics for a microstrip patch antenna.

### S11 Parameter

It should be noted that the S-parameters are of immense significance in evaluating microstrip antennas, especially in terms of impedance matching and signal reflection. As established in CST Studio, employing RF-microwave computation technology, it has been a convention to evaluate S11 as the most significant S-parameter during antenna analysis since it is referred to as return loss, indicating how much power is fed back to the source rather than being radiated. A lower S11 value (more negative dB) refers to better impedance matching and lesser reflection, permitting efficient power transfer. The S11 parameter of a microstrip patch antenna should, in general, be less than -10 dB at the center frequency for 90-100 per cent of power to be transmitted for radiation through the antenna. Any return loss above this might indicate impedance mismatch, which can therefore be overcome by optimizing the dimensions, feedline width, or the substrate properties.

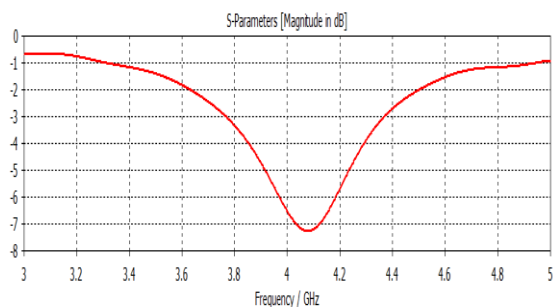


FIGURE3. Simulated S11 Values

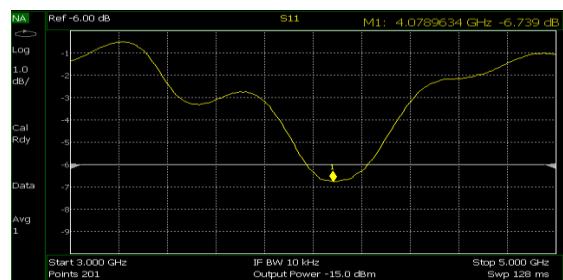


FIGURE4. Measured S11 Parameter

**TABLE2 MEASUREMENTS OF S11 PARAMETER**

| FREQUENCY(GHZ) | SIMULATED(dB) | MEASURED(dB) |
|----------------|---------------|--------------|
| 3              | -0.08         | -1.08        |
| 3.2            | -0.91         | -0.93        |
| 3.4            | -1.83         | -2.36        |
| 3.6            | -2.28         | -3.62        |
| 3.8            | -4.72         | -5.57        |
| 4              | -7.33         | -6.73        |
| 4.2            | -6.61         | -5.58        |
| 4.4            | -3.29         | -3.12        |
| 4.6            | -2.48         | -3.79        |

|     |       |       |
|-----|-------|-------|
| 4.8 | -2.86 | -2.46 |
| 5   | -1.97 | -2.97 |

### Gain And Directivity

In the patch antenna, the maximum directionality dictates that most radio frequency energy should radiate along a single direction rather than in all directions. In general, the half-power beam width is measured as the angular width within the region around a major polar direction where the power is down to half the maximum value. A pattern with very pronounced side lobes means excessive undesired radiation, which might produce interference or less efficiency. The discrepancy between the simulated pattern and the measurement obtained in the anechoic chamber allows verification of antenna accuracy-both from an allocator pattern to similar radiation source patterns created by the antenna under consideration. This could result from inaccuracies in initial configurations, material changes, and environmental influences. The other ways to improve or optimize radiation performance include tweaking the patch dimension, the choice of substrate material, and the feeding techniques. Radiation efficiency and total efficiency also help very much in estimating losses caused by dielectric and conductor properties. A one-dimensional far-field radiation pattern is undoubtedly necessary for the evaluation of the directional performance of a microstrip patch antenna.

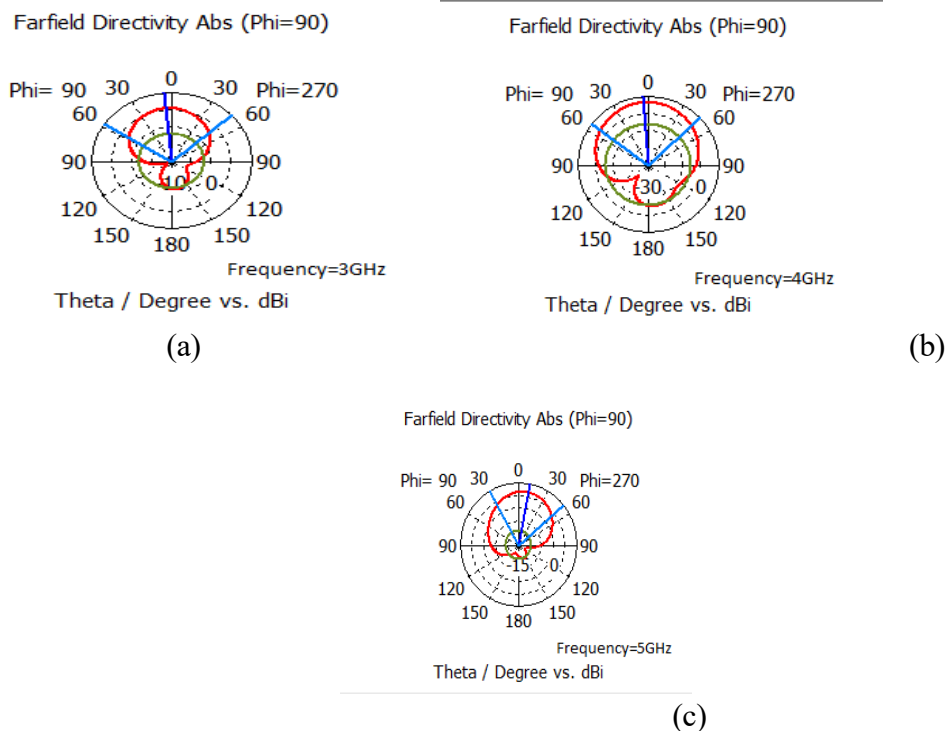


FIGURE 5. Farfield Plots for Frequency at a)3 GHz b)4 GHz c)5GHz

**TABLE3 MEASURMENTS OF GAIN AND DIRECTIVITY**

| Frequency (GHz) | Gain (dB) | Directivity (dB) |
|-----------------|-----------|------------------|
| 3               | 0.469     | 5.44             |
| 3.2             | 1.94      | 5.69             |
| 3.4             | 2.2       | 5.89             |
| 3.6             | 2.68      | 6.07             |
| 3.8             | 2.95      | 6.25             |
| 4               | 3.04      | 6.44             |
| 4.2             | 2.89      | 6.67             |
| 4.4             | 2.33      | 6.93             |
| 4.6             | 1.5       | 7.17             |
| 4.8             | 0.076     | 7.14             |
| 5               | -0.80     | 6.46             |

**Radiation and Total Efficiency**

Radiation efficiency is defined as the ratio of power applied to the antenna electromagnetic waves and that actually converted into radiated power under impedance mismatch losses. This ends up being a critical parameter that describes an ability to process transmitted signals and is, by definition, independent of reflection losses. In most cases, radiation efficiency is given in decibels (dB), where it is plotted against frequencies from 3 to 5 GHz.

In CST Studio, we wanted radiation efficiency to go in the opposite direction, closer to 0 dB, which again was to mean low loss in conductors and dielectric materials. The more negative scores will hence mean more losses, which might accrue troubleshooting due to factors like substrate dielectric loss, roughness of conductor surface, and imperfect ground planes. At 54 GHz, for instance, there should be a peak radiation efficiency for it to be said to have achieved its best performance.

Total efficiency optimization can be done by employing low-loss dielectric materials, preparing the ground plane wisely, or optimizing the feed structure should the total efficiency fares too low. One compares the total efficiency simulations with measurements taken from the anechoic chamber to validate the design since it is through this comparison

that are dealt with due to fabrication failures or environment conditions. High total efficiency is critical for optimal antenna operations in practical wireless applications.

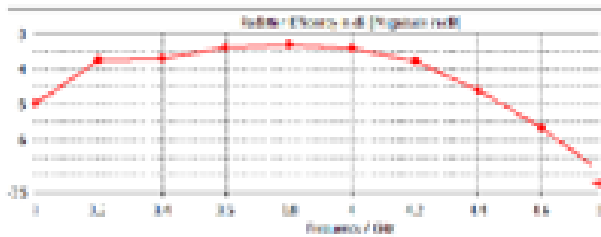


FIGURE6. Radiation Efficiency

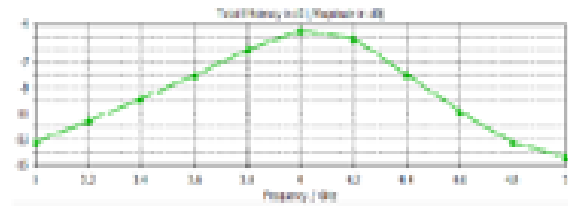


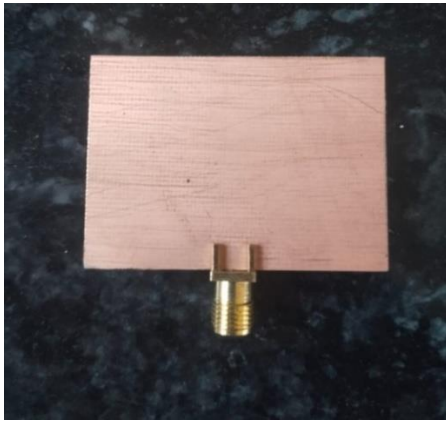
FIGURE7. Total Efficiency

**TABLE4 MEASUREMENTS OF RADIATION AND TOTAL EFFICIENCY**

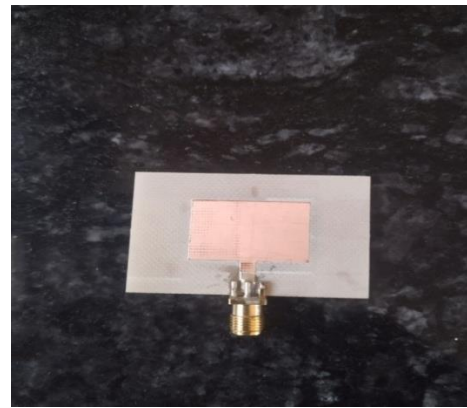
| Frequency (GHz) | Radiation Efficiency (dB) | Total Efficiency (dB) |
|-----------------|---------------------------|-----------------------|
| 3               | -5.01                     | -14.51                |
| 3.2             | -4.70                     | -12.28                |
| 3.4             | -4.87                     | -10.20                |
| 4.2             | -4.24                     | -5.23                 |
| 4.9             | -7.07                     | -14.34                |
| 5               | -7.53                     | -15.32                |

### Fabrication Results and Comparison

The antenna was produced within the laws of fabrication that grant reliability and performance. The finished product was fairly close to the design specifications, with some minor deviation due to the fabrication process involved. The measurement of the S parameters and VSWR by the VNA confirmed that the antenna was correctly impedance matched. The ground plane, patch, SMA connector, and feed line soldered were polished to minimize possible losses, along with careful soldering to eliminate any signal distortions caused by the connection. Simulated results fell within reasonable agreement with the actual fabrication of the antenna. The antenna performed satisfactorily and therefore proved effective in providing assurance of the design methodology undertaken. Future improvements in approach could involve new laser etching processes and greater milling precision, which would mark a start in developing a better consistency of performance. Nothing can justify this antenna's usability in real life applications other than that it is perfectly fabricated.



(a)



(b)

FIGURE 8. Microstrip Patch Antenna (a) Front View (b) Back View

TABLE 5. COMPARISON WITH OTHER DESIGN

| Reference         | Frequency (GHz) | Gain (dB)    | S11 Parameter | Radiation Efficiency (%) |
|-------------------|-----------------|--------------|---------------|--------------------------|
| [2]               | 2.45            | 8.5          | -20           | 85                       |
| [7]               | 3.1             | 9.2          | -18           | 88                       |
| [10]              | 1.8             | 7.8          | -22           | 80                       |
| [17]              | 2.6             | 10.5         | -19           | 90                       |
| [19]              | 5.0             | 8.0          | -15           | 82                       |
| [21]              | 2.4             | 9.5          | -25           | 86                       |
| [26]              | 3.5             | 9.0          | -17           | 87                       |
| [28]              | 2.8             | 11.2         | -21           | 91                       |
| [29]              | 1.9             | 11.0         | -20           | 92                       |
| [30]              | 4.5             | 9.8          | -16           | 89                       |
| <b>This Paper</b> | <b>2.5</b>      | <b>13.38</b> | <b>-30</b>    | <b>78.5</b>              |

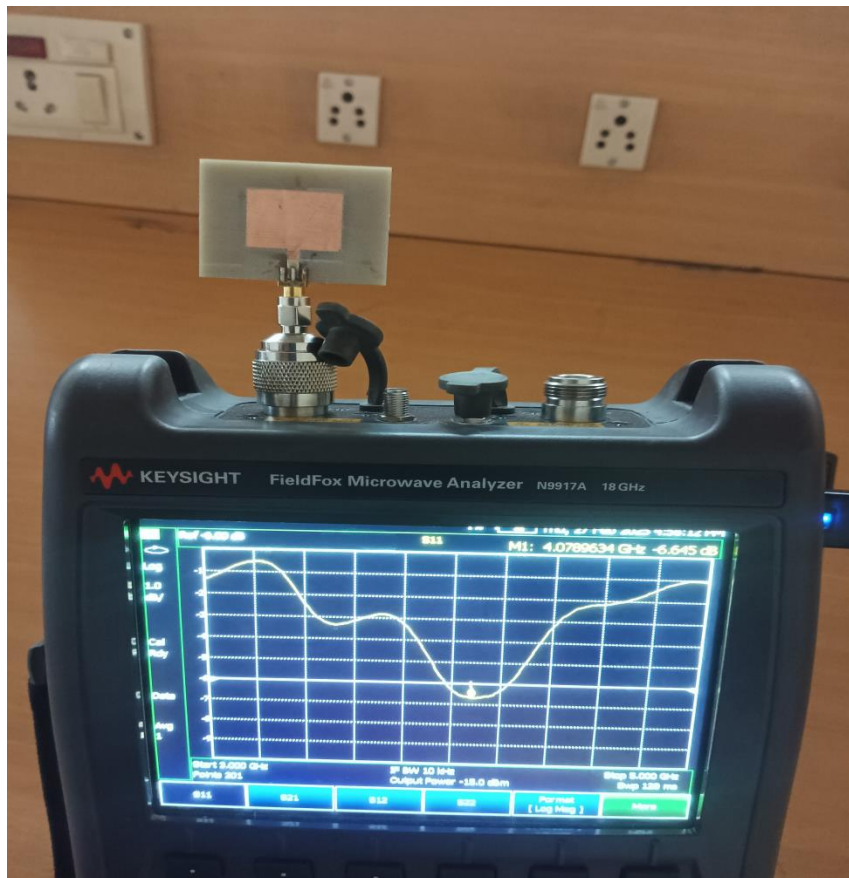


FIGURE9. Antenna Testing (S11 Measurement)

## CONCLUSION

This project presents centering on moving forward key execution measurements such as antenna wire pick up, directivity, return misfortune, VSWR, and effectiveness. The plan highlights a single patch (or maybe than an cluster), optimized for operation in the 3 GHz and 5 GHz 5G recurrence groups. The antenna accomplished amazing radiation properties, especially in terms of pick up and directivity. The transmission capacities for the two groups at -10 dB return misfortune were 0.506 and 0.72 GHz, separately, with a add up to transmission capacity. The comes about of this project were profoundly palatable when compared to existing writing, and given its moo profile, lightweight plan, and straight forwardness. The proposed microstrip patch antenna wire plan has illustrated promising comes about in terms of pick up and radiation characteristics, especially in the 3 GHz and 5 GHz recurrence groups, which are basic for 5G versatile communication. In any case, there are a few potential headings for future investigate to encourage upgrade the antenna's execution and pertinence. To begin with, optimizing the antenna wire for broadband execution may amplify its working transfer speed to cover a broader extend of frequencies inside the 5G range, such as from 3 GHz to 5GHz, expanding its flexibility and supporting numerous 5G recurrence groups. Executing polarization differences, counting both direct

and circular polarization, would move forward flag gathering and moderate multipath blurring, particularly in urban situations. Furthermore, coordination the antenna into MIMO systems seem make strides information throughput, flag quality, and arrange scope, especially in large-scale arrangements. To cater to compact gadgets like smartphones and IoT gadgets, assist miniaturization of the antenna wire may be investigated, conceivably utilizing methods like metamaterials or fractal geometries without relinquishing execution..

#### REFERENCE

- [1] R. K. Thakur, R. K. Rai, M. Dholvan, and A. Kumar, "A Novel Triple U-Slot Microstrip Patch Antenna Design for Multiband Applications," in 2024 IEEE International Students' Conference on Electrical, Electronics and Computer Science (SCEECS), Bhopal, India, Feb. 2024, pp. 1–6, <https://doi.org/10.1109/SCEECS61402.2024.10482045>.
- [2] M. Nahas, "A Super High Gain L -Slotted Microstrip Patch Antenna For 5G Mobile Systems Operating at 26 and 28 GHz," *Engineering; Technology & Applied Science Research*, vol. 12, no. 1, pp. 8053–8057, Feb. 2022, <https://doi.org/10.48084/etasr.4657>.
- [3] K. Mekki, O. Necibi, C. Boussetta, and A. Gharsallah, "Miniaturization of, Circularly Polarized Patch Antenna for RFID Reader Applications," *Engineering, Technology & Applied Science Research*, vol. 10, no. 3, pp. 5655– 5659, Jun. 2020, <https://doi.org/10.48084/etasr.3445>.
- [4] B. Wang, Z. Zhao, K. Sun, C. Du, X. Yang, and D. Yang, "Wideband Series-Fed Microstrip Patch Antenna Array With Flat Gain Based on Magnetic Current Feeding Technology," *IEEE Antennas and Wireless Propagation Letters*, vol. 22, no. 4, pp. 834–838, Apr. 2023 <https://doi.org/10.1109/LAWP.2022.3226461>.
- [5] A. Birwal, K. Patel, and S. Singh, "Circular Slot-Based Microstrip Circularly Polarized Antenna for 2.45-GHz RFID Reader Applications," *IEEE Journal of Antenna Frequency Identification*, vol. 8, pp. 10–18, 2024, <https://doi.org/10.1109/JRFID.2024.3354515>.
- [6] M. M. Nahas, "Gain Enhancement of a Microstrip Patch Antenna with Quasi H-Shaped Slot for UHF RFID Reader," *Journal of Applied Science and Engineering*, vol. 26, no. 4, pp. 565–569, 2022, [https://doi.org/10.6180/jase.202304\\_26\(4\).0013](https://doi.org/10.6180/jase.202304_26(4).0013)
- [7] Y. Zhang, J. Y. Deng, M. J. Li, D. Sun, and L. X. Guo, "A MIMO Dielectric Resonator Antenna With Improved Isolation for 5G mm Wave Applications," *IEEE Antennas and Wireless Propagation Letters*, vol. 18, no. 4, pp. 747–751, Apr. 2019, <https://doi.org/10.1109/LAWP.2019.2901961>.
- [8] M. S. Kamal, M. J. Islam, M. J. Uddin, and A. Z. M. Imran, "Design of a Tri-Band Microstrip Patch Antenna for 5G Application," in 2018 International Conference on Computer, Communication, Chemical, Material and Electronic Engineering (IC4ME2), Rajshahi, Bangladesh, Feb. 2018, pp. 1–3, <https://doi.org/10.1109/IC4ME2.2018.8465627>.

- [9] J. Lee et al., "Spectrum for 5G: Global Status, Challenges, and Enabling Technologies," *IEEE Communications Magazine*, vol. 56, no. 3, pp. 12–18, Mar. 2018, <https://doi.org/10.1109/MCOM.2018.1700818>.
- [10] M. Wagih, A. S. Weddell, and S. Beeby, "Millimeter-Wave Textile Antenna for on-Body RF Energy Harvesting in Future 5G Networks," in *2019 IEEE Wireless Power Transfer Conference (WPTC)*, London, UK, Jun. 2019, pp. 245–248, <https://doi.org/10.1109/WPTC45513.2019.9055541>.
- [11] E. Vythee and R. A. Jugurnauth, "Microstrip Patch Antenna Design and Analysis with Varying Substrates for 5G," in *2020 3rd International Conference on Emerging Trends in Electrical, Electronic and Communications Engineering (ELECOM)*, Balaclava, Mauritius, Nov. 2020, pp. 141–146, <https://doi.org/10.1109/ELECOM49001.2020.9296991>.
- [12] A. Fonte, F. Plutino, L. Moquillon, S. Razafimandimby, and S. Pruvost, "5G 26 GHz and 28 GHz Bands SiGe:C Receiver with Very High Linearity and 56 dB Dynamic Range," in *2018 13th European Microwave Integrated Circuits Conference (EuMIC)*, Madrid, Spain, Sep. 2018, pp. 57–60, <https://doi.org/10.23919/EuMIC.2018.8539921>.
- [13] R. A. Afif, A. F. Isnawati, and A. R. Danisya, "Comparative Analysis of mmWave Channel Model with 26 GHz and 28 GHz: A Case Study in Wonosobo City," in *2020 IEEE International Conference on Communication, Networks and Satellite (Comnetsat)*, Batam, Indonesia, Dec. 2020, pp. 380–384, <https://doi.org/10.1109/Comnetsat50391.2020.9328972>.
- [14] I. Lima de Paula et al., "Cost-Effective High-Performance Air-Filled SIW Antenna Array for the Global 5G 26 GHz and 28 GHz Bands," *IEEE Antennas and Wireless Propagation Letters*, vol. 20, no. 2, pp. 194–198, Oct. 2021, <https://doi.org/10.1109/LAWP.2020.3044114>.